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REPORT

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PERFORMANCE EVALUATION
OF A
POSITIVE-PRESSURE TRANSPORT CAPTSTAN

December 1965

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FOREWORD

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[redacted] submits this report in compliance with the
requirements of [redacted]

Approved:

Research Manager

ABSTRACT

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An investigation was conducted on a new technique for generating and applying a vacuum to a rotating film-drive capstan. The diameter of the capstan was established as a result of the tests conducted under Assignment [] A series of tests was run to establish the operating parameters of such capstans on different widths of film, wet and dry, when positive pressure was used to generate the vacuum and when the vacuum was applied in the conventional manner. Blower output in the two modes of operation was measured and losses through the capstan recorded. Conventional vacuum operation provided torques three to four times higher than the positive pressure method.

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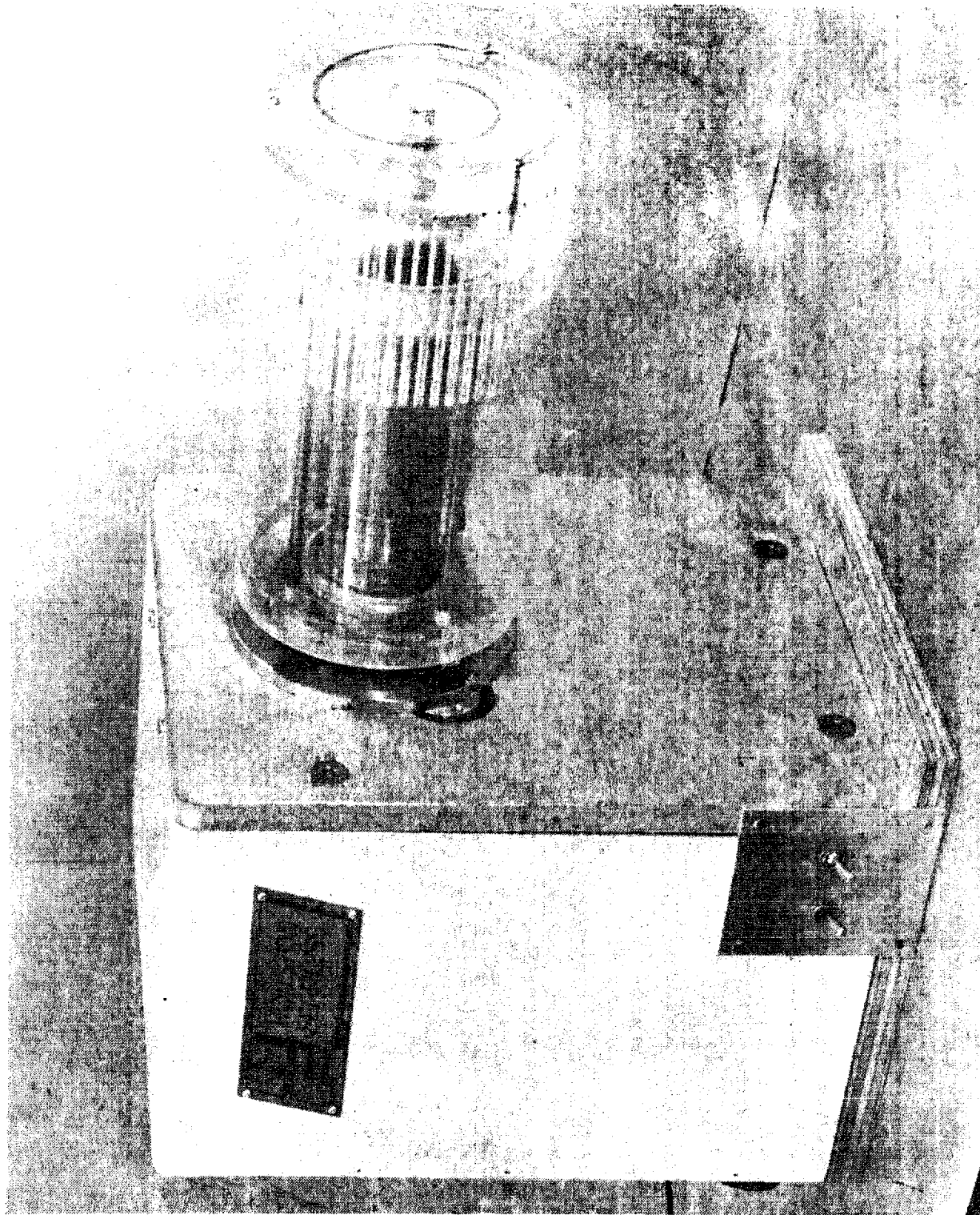
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SECTION 1
INTRODUCTION

A program of investigation on a new technique for generating and applying a vacuum to a rotating film-drive capstan was conducted. This technique involves the generation of a vacuum by passing high-velocity air through a shaped annular orifice and connecting vacuum lines to openings in the throat of this orifice.

Two capstans were fabricated for this program. The first one, 3-inches in diameter, was used to obtain the data presented (Figures 2-2 and 2-3). A second capstan (Figure 1-1) is a working model that will drive all film widths from 70mm to 9-1/2-inches in base thicknesses to 0.012-inch. It is 6-inches in diameter so that undue forces will not be required for the sole purpose of bending film. This latter is the capstan on which most of the experimental test data incorporated in this report was obtained.

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Vacuum Capstan Test Model

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Figure 1 -



SECTION 2

TECHNICAL DISCUSSION

2.1 "POSITIVE-PRESSURE" VACUUM CAPSTAN PRINCIPLE

The vacuum capstan is operated on the venturi principle to generate a vacuum in the rotating member of the capstan. Figure 2-1 shows a cross-section of a positive pressure capstan, illustrating the principle of generating a vacuum in an annular orifice.

Under positive pressure, air enters the capstan parallel to the axis of rotation. The air is deflected outward so that it exits from the capstan radially to the axis of rotation between a fixed and rotating member. A circle of maximum restriction is found between the two members. This is shown at point B in Figure 2-1. The pressure at this restriction point is inversely proportional to a function of the velocity of the air passing through it. The capstan was so constructed that the annular opening at point B could be varied to obtain maximum effectivity at the fixed blower output.

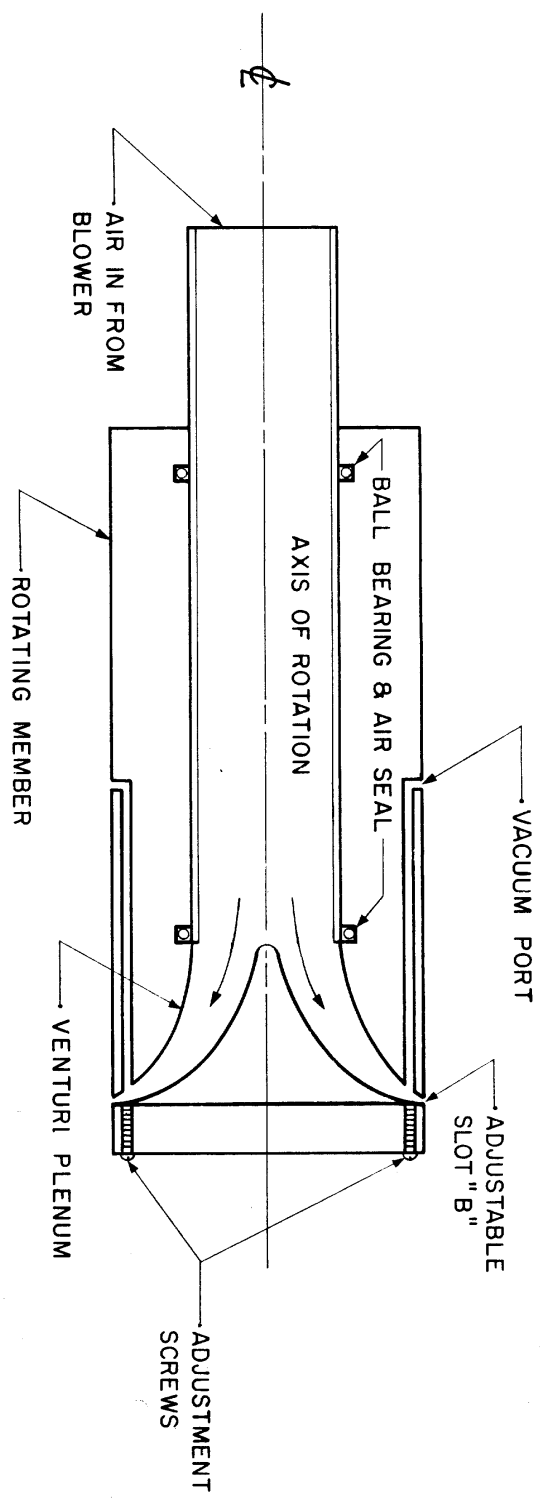


Figure 2-1. Positive-Pressure Vacuum Capstan

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A total of 64 openings were made around the circumference of the capstan at the throat of the annular orifice to create a multiplicity of vacuum ports (three, however, were obscured by attaching screws leaving only 57 effective). Each of these vacuum ports is connected to the surface of the rotating member of the capstan at the point where it is desired to drive the film. The diameter of the ports at this point is 0.063-inch. In this case, it is near the midpoint of the capstan so that all sizes of film can be driven.

The force holding the film to the capstan is dependent on the differential pressure on the two sides of the film and the area over which this differential pressure is applied. A greater driving force for the film can be created by increasing the area served by each vacuum port on the capstan. This can be done by providing a rough surface around each port or by providing a pattern of grooves connected to each port.

Most capstans are required to hold film over a fixed angle, which is related to the angle of rotation. This is usually 180 degrees or less, depending on the configuration of the machine in which they are used. It is necessary that the capstan release the film at a point

beyond the film wrap. This is done with the positive pressure capstan by providing a vane on the fixed member, across the outlet of the orifice, so that back pressure is created to reduce the velocity through the throat at the desired release point. If a high enough back pressure is obtained, this will not only eliminate the vacuum but will also provide a positive pressure to separate the film from the rotating capstan.

A set of tests was conducted on the 3-inch capstan to determine vacuum pressure in inches of mercury as a function of the volume, or volume of air per minute used. These results are shown in Figures 2-2 and 2-3. Each is an average of four vacuum ports in one particular position; that is, having one relationship to the fixed member. These positions are indicated as A and B on the curves. Above a volume rate of about 6 cubic feet per minute, the curve remains linear from the volume rate of flow. The break in these curves is unexplained at this time.

2.2 TEST PROCEDURE

The first series of tests on the 6-inch capstan was designed to determine the most efficient gap width, i.e. the one producing the highest vacuum. By using combinations of three different thicknesses of standard shim stock (2, 5 and 9 mils), the gap could be varied in 1-mil increments. Each setting was checked carefully with a feeler gage. One leg of a 2:1 slope inclined mercury manometer was attached to orifice No. 10 (midway between two of the adjusting screws by means

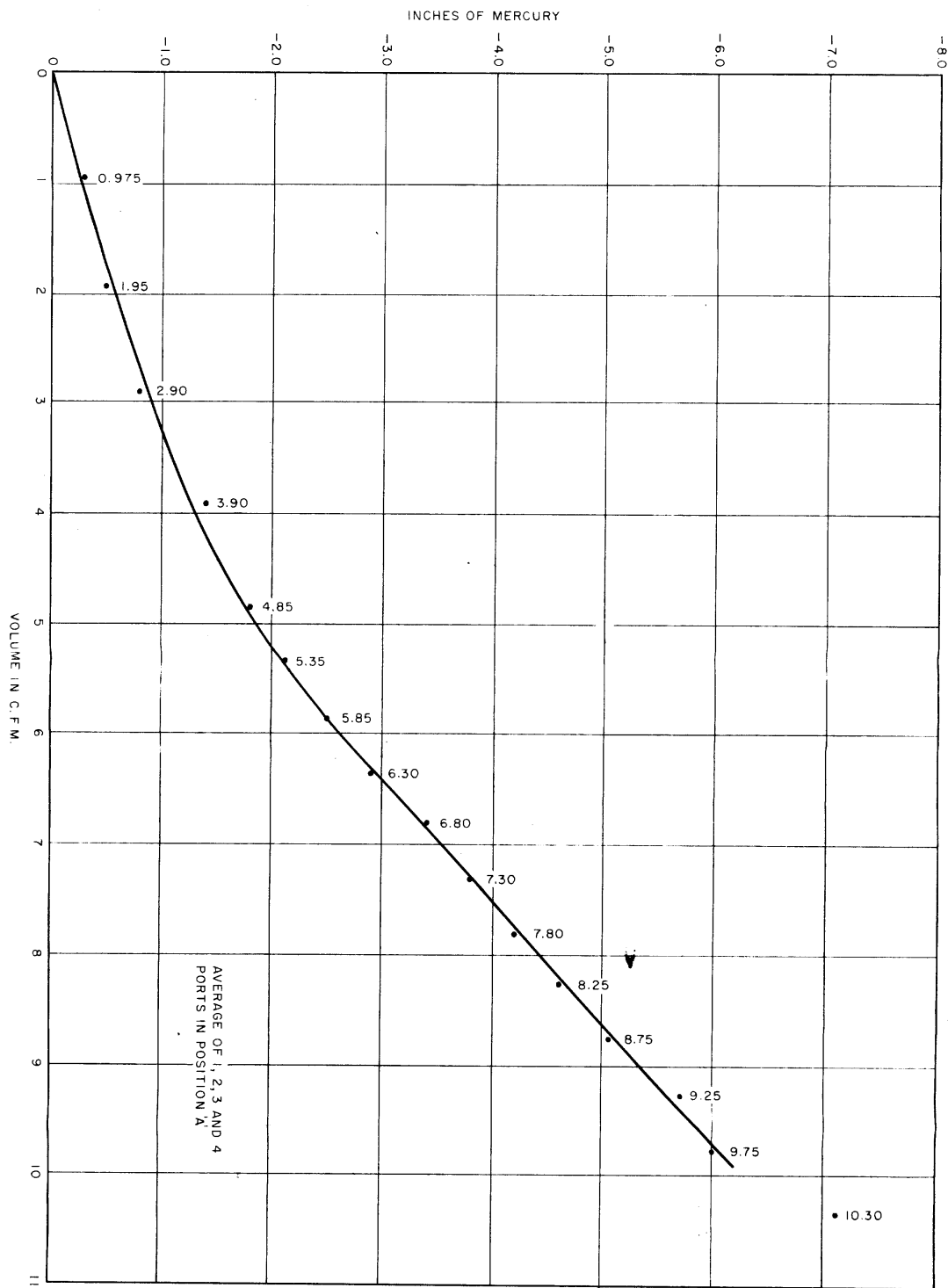
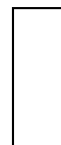
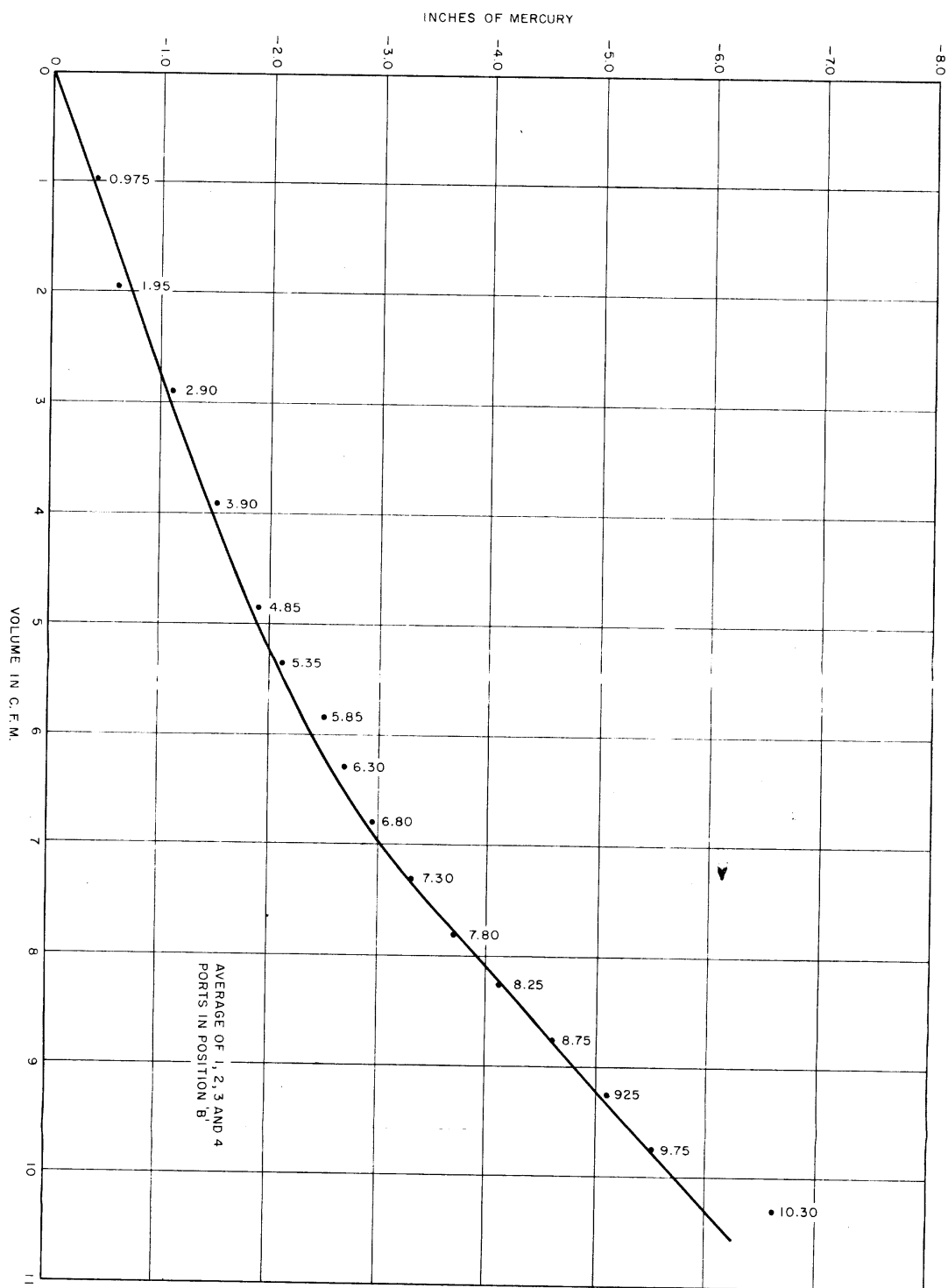


Figure 2-2. Vacuum Pressure as a Function of Volume with Ports in Position "A"

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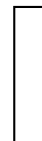


Figure 2-3. - Vacuum Pressure as a Function of Volume with Ports in Position "B"

of a sealed pressure tap. Several readings were taken at other points on the perimeter to check the accuracy of the measurement and, in all cases, it fell within the reading error of the instrument, $\pm .02$ -inches.

The results are tabulated, Table 2-1, and graphed, Figure 2-4. A sharp break can be observed in the curve between 6 and 7 mils and 7 was selected as the optimum point. At 5 mils, the unit was quite unstable and fluctuated rapidly between 2.80 and 3.15-inches of mercury. The measurements were made with all the orifi open except the one under test, the ones on either side of it (No.'s 9 and 11) and the three obscured by the adjusting screws (No. 1, 21 and 41).

At this point, a construction-board plenum, 1-1/2-inches wide, 1/2-inch deep with 1/2-inch flanges on either side, was built to check a phenomenon observed at an earlier point in the program; namely, that covering some of the orifi seemed to drop the total vacuum in those remaining. Despite being heavily coated with shellac, porcelain and silicone cements, the experimental unit did not bear out anticipated results. When carefully sealed to the capstan's periphery, the highest reading obtained with all orifi open was 2.03-inches of mercury. It was felt that this reading should theoretically have agreed more closely with the "high" of Table 2-1, 4.95-inches. The reading at orifice No. 10, above was repeated and the slot width "tuned" while the blower was running. It proved possible to increase the former 4.95 reading to 5.49-inches of mercury. When the top 180-degrees of openings were

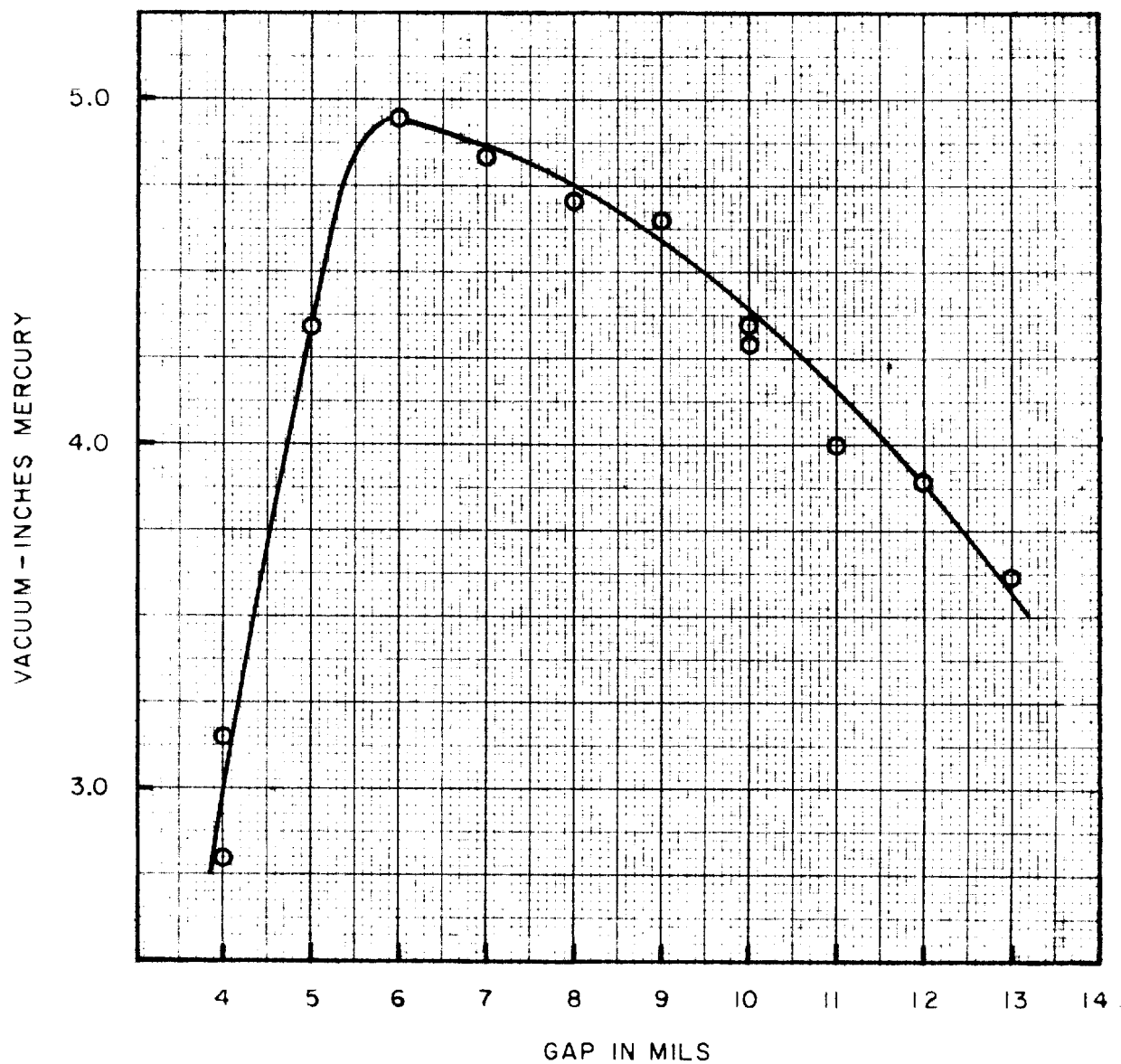


Figure 2-4. Gap Width Determination for 6-Inch Positive-Pressure Transport Capstan

TABLE 2-1

Gap Width Determination for 6-Inch Positive
Pressure Transport Capstan

<u>Run</u>	<u>Room Temp.</u> <u>°F</u>	<u>Gap</u> <u>Mils</u>	<u>Vacuum</u> <u>Inches Hg.</u>
1	72.88	14	3.61
2	72.72	16	3.11
3	73.08	10	4.41
4	73.27	11	4.31
5	73.39	11	4.34
6	73.71	12	4.00
7	73.76	13	3.90
8	73.90	10	4.65
9	74.08	9	4.72
10	73.62	8	4.84
11	73.91	7	4.95
12	73.92	6	4.34
13	74.06	5	2.80-3.15*

* Very erratic and unstable

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blocked off, the loss was slight, 5.41-inches. Masking all orifi except No. 10 raised the reading to 5.63.

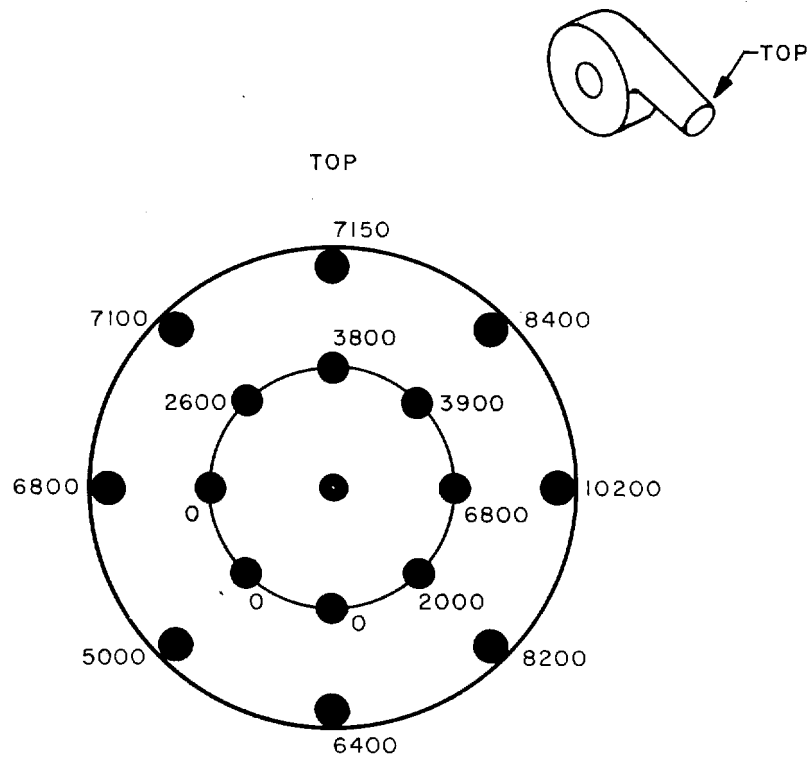
It can logically be concluded from these foregoing tests that this capstan configuration is not sensitive to changes in the number of covered orifi and, consequently, does not require complex baffles or valving to cut off suction in the open portion of its periphery.

2.3 FLOW OUTPUT OF [] BLOWER

The blower used in all the capstan tests was manufactured by the [] Model No. IS 115210, using an Alnor Velometer, Type 3002, No. 24160, a series of static pressure readings and flow in fpm was made (Table 2-2) at each port with the annular opening at B adjusted for maximum. For a second test, a complete pressure traverse of the blower output was recorded to determine cfm (Figure 2-5). Because of the erratic flow pattern in the narrow throat of the blower (three points at 180°, 225°, and 270° read zero), it was decided to measure the total output of the blower with a recording flowmeter.

Subsequently, a large [] meter was borrowed from the []. This meter has a capability of registering 23,000 cubic feet per hour in increments of 10 cubic feet at pressures up to 125 pounds per square inch. It is a Model No. 23M125, Serial No. 6504026, with calibration file No. 637-17-N65. It was 0.7 percent slow at 2300 cfm and 1.6 percent slow at 23,00 cfm.

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I-D OF BLOWER OUTLET = 1-7/8 IN.
 CFM = AVERAGE VELOCITY (FPM) x AREA (SQ. FT.)

$$= \frac{4680 \times 2-3/4}{144} = 179 \text{ CFM}$$

Figure 2-5. Measurement of Blower Performance in Cubic Feet per Minute

TABLE 2-2
NEGATIVE FLOW CHECKS OF CAPSTAN

No. of Holes = 57 Effective
Diameter of Holes = 0.063 Inch

Hole Sta	Static Press Ins/H ₂ O	Fpm	Hole Sta	Static Press Ins/H ₂ O	Fpm	Hole Sta	Static Press Ins/H ₂ O	Fpm
1	Screw	Screw	22	1.85	1525	43	1.1	1575
2	.95	1150	23	2.0	1550	44	1.2	1350
3	.95	1150	24	2.0	1550	45	1.6	1550
4	1.6	1400	25	2.3	1650	46	1.4	1475
5	1.7	1400	26	1.9	1650	47	1.5	1475
6	1.7	1425	27	2.3	1650	48	1.5	1450
7	1.7	1450	28	2.2	1700	49	1.4	1425
8	1.7	550	29	2.0	1650	50	1.4	1350
9	1.6	1425	30	2.2	1600	51	1.4	1375
10	1.9	1550	31	2.2	1650	52	1.4	1400
11	1.8	1510	32	1.9	1725	53	1.2	1300
12	2.0	1550	33	1.8	1700	54	1.5	1300
13	1.9	1525	34	1.9	1550	55	1.5	1425
14	2.0	1550	35	1.9	1525	56	1.4	1325
15	1.95	1525	36	2.0	1650	57	1.0	1400
16	2.0	1575	37	2.1	1700	58	1.4	1475
17	2.4	1700	38	1.7	1600	59	1.4	1440
18	.30	700	39	1.6	1550	60	1.0	1300
19	1.7	1470	40	1.2	1350			
20	1.75	1470	41	Screw	Screw			
21	Screw	Screw	42	.95	1200			

(Figure 2-6 is the calibration chart for the meter). An adapter flange was built to receive the blower fan and bolt directly onto the meter housing. Preliminary tests indicated the possibility of erroneous high readings due to the velocity impingement effect of the blower output so close to the flowmeter's vanes. To avoid this contingency, a test setup (Figures 2-7, 2-8, 2-9 and 2-10) was made in which a large plywood barrel, sealed inside and out with two coats of liquid plastic and silicone mastic, was introduced between the blower and meter to act as an expansion plenum.

The full blower output was then measured with no constriction in its outlet nozzle (Table 2-3, Run 1). The cubic feet of air was calculated by timing the flowmeter with a stopwatch and correcting the reading with the calibration chart (Figure 2-6). Note the rapid rise in temperature in the plenum due to mechanical energy added by the fan. Several repeat runs were made for different total times to prove 1400 cubic feet sufficient for mensuration accuracy.

The capstan was then introduced between the blower and the plenum. A silicone plastic seal (Figure 2-7) was made midway between the venturi slot and the suction orifi. Runs 2 and 5, Table 2-3, were made with all orifi open and runs 3 and 4 with them closed. The difference between the two readings represents the total cfm of air passing through the suction orifi, in this case 3.87 cfm. Runs 2 and 3 were considered less accurate than 4 and 5, as there was evidence of a

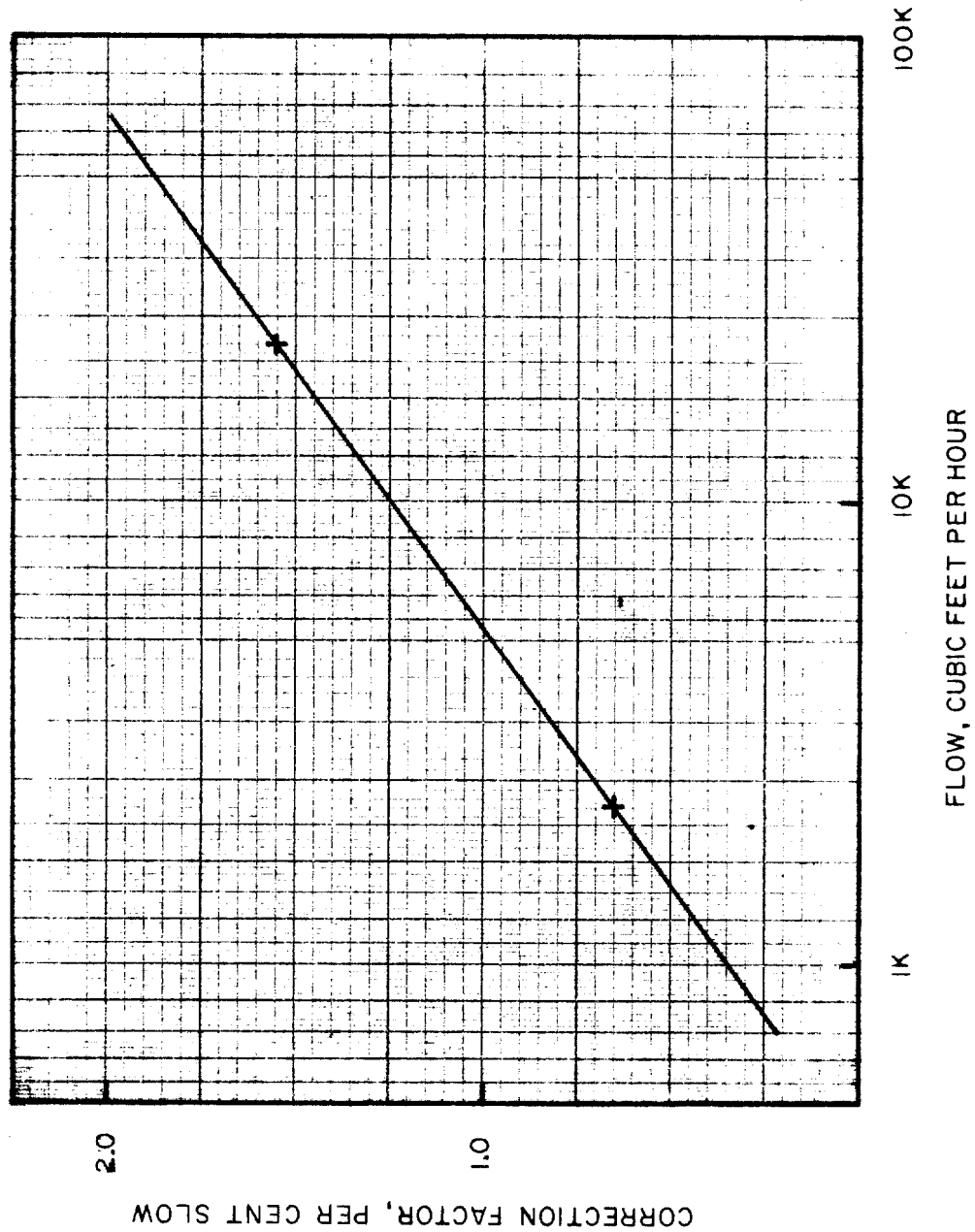


Figure 2-6. Calibration Chart for Meter - No. 6504026

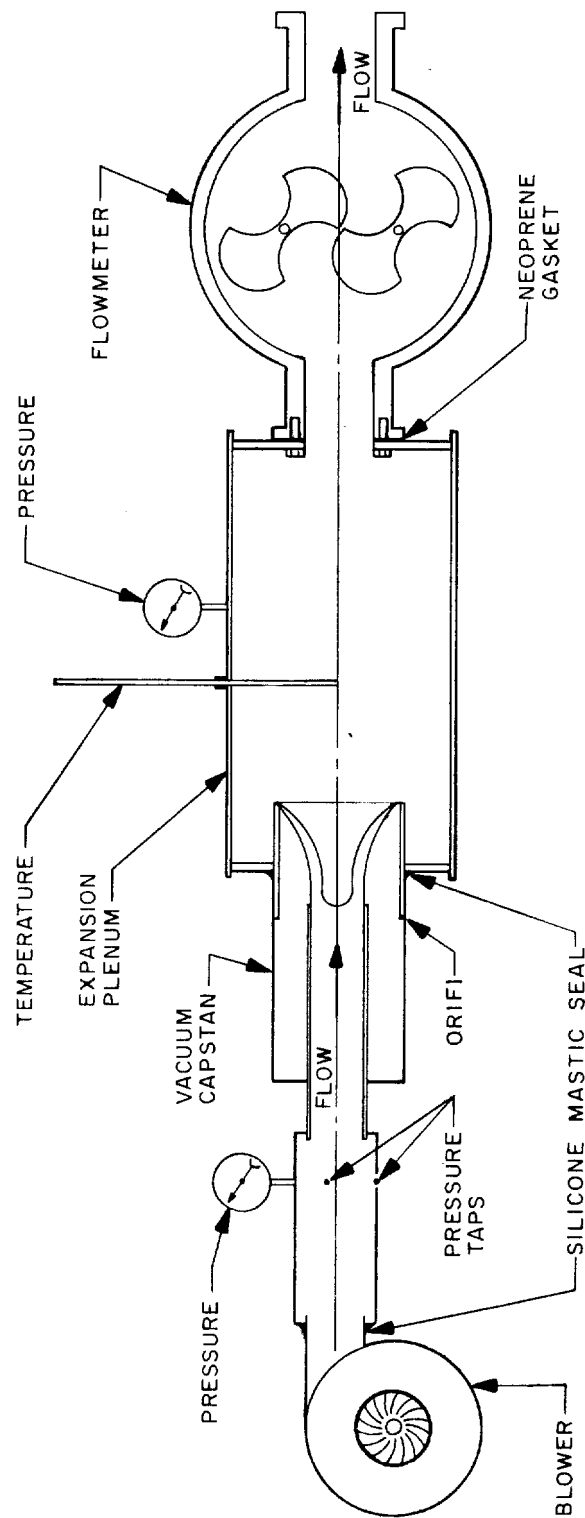


Figure 2-7. Test Setup Schematic for Vacuum Capstan - Pressure Mode

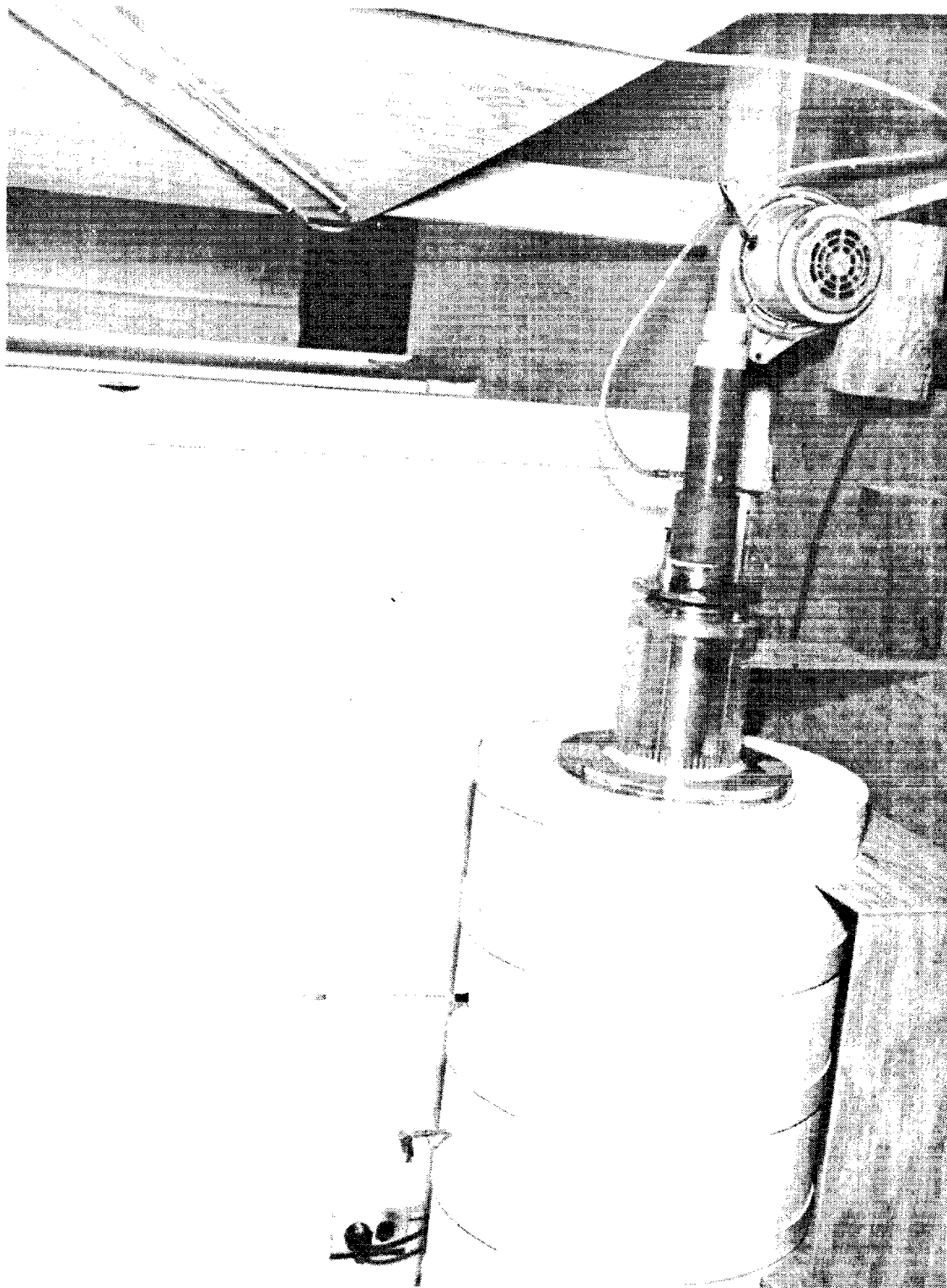


Figure 2-3. Front View of Vacuum Capstan Apparatus (Pressure Mode) Showing Inclined Manometer in Use

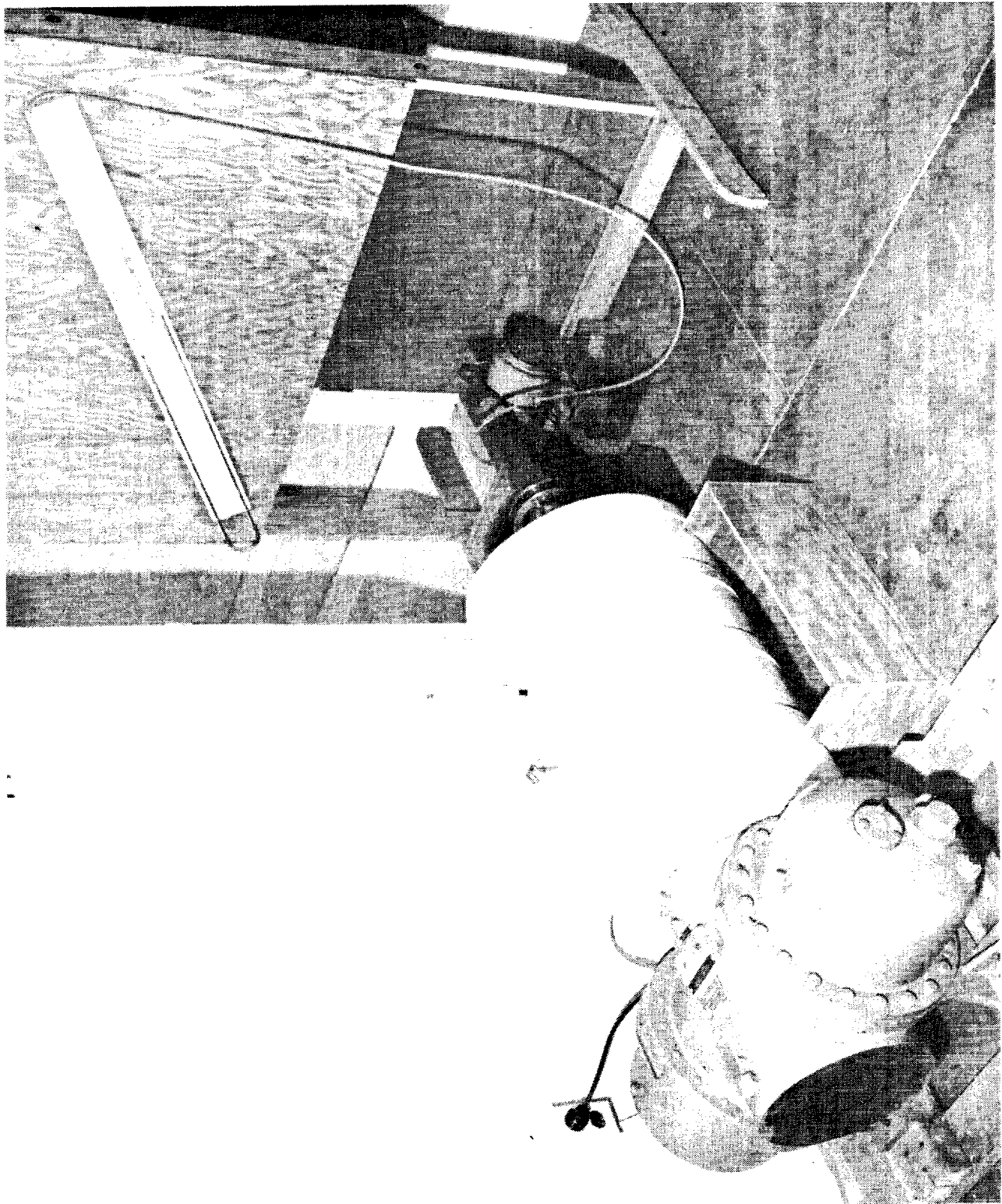


Figure 2-9. Side View of Vacuum Galvanometer Apparatus - Pressure Mode

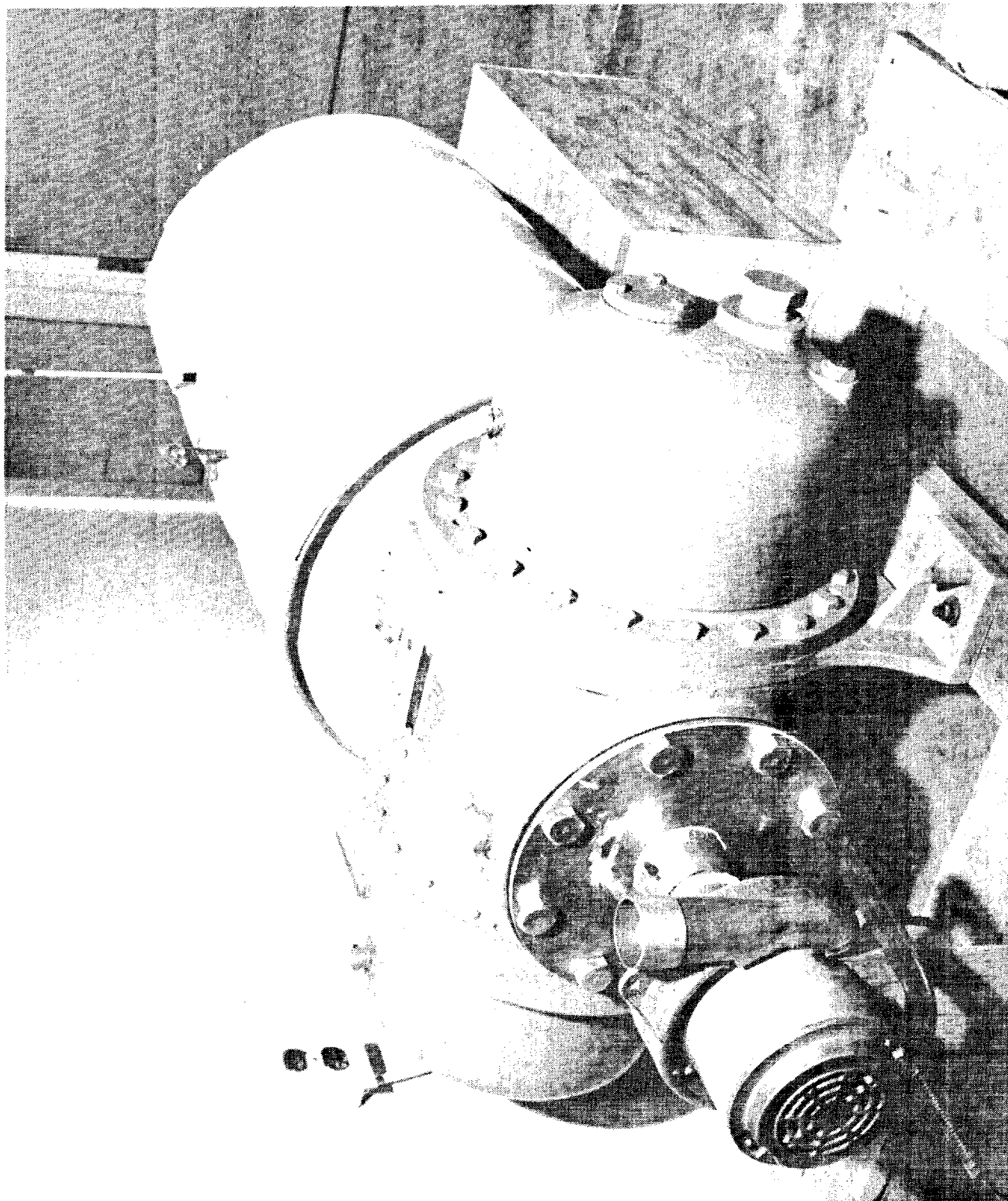


Figure 2-10. Rear View of Vacuum Capstan Apparatus - Vacuum Mode

TABLE 2-3. Blower Output and Capstan Efficiency (Pressure Mode of Operation)

Run	Room Temp. T ₁ °F	Plenum Temp. T ₂ °F	Inches Hg P ₁	Inches Hg P ₂	Flowmeter Reading	Time	Corrected Flow CFM
1 (a)	78.15	98.56	0.04	0.04	183	0	
	76.87	102.20	0.02	0.02	187 ⁺	5 min	
	76.42	103.29	0.02	0.02	192 ⁺	10	
	76.32	104.72	0.02	0.02	197	14 min, 55.2 sec.	94.77
2 (b)	74.16	79.35	0.0	0.0	198	0	
	74.69	96.80	0.01	0.01	199 ⁺	6 min	
	75.00	100.01	0.02	0.02	201	9 min, 44.8 sec.	31.51
3 (c)	75.25	105.26	0.02	0.02	203	0	
	75.71	108.14	0.02	0.02	204	4 min	
	75.97	110.13	0.02	0.02	205 ⁺	9	
	76.14	110.66	0.02	0.02	206	12 min, 0.2 sec.	25.54
4 (c)	75.01	83.50	5.64	5.64	210	0	
	75.34	97.50	5.65	5.65	211 ⁺	3 min	
	75.62	102.91	5.68	5.68	211 ⁺	6	
	75.78	105.43	5.72	5.72	212 ⁺	9	
5 (b)	75.94	107.95	5.71	5.71	213 ⁺	12	
	76.13	108.85	5.75	5.75	214	15 min, 4.8 sec.	26.70
5 (b)	76.46	101.15	5.79	5.79	216	0	
	76.59	104.00	5.78	5.78	216 ⁺	3 min	
	76.82	106.35	5.77	5.77	217 ⁺	6	
	77.11	107.96	5.76	5.76	219	9 min, 52.4 sec.	30.57

Notes:

(a) Fan Alone

(b) Fan and Capstan - All Orifi Open

(c) Fan and Capstan - All Orifi Closed

transient leak in one of the gaskets during the former runs. The latter, then, are repeats. Blower output dropped to 28.1 percent through the constriction of the 7-mil venturi slot. Checks were made at four different locations on the blower outlet nozzle to note the amount of change in the static pressure (Figure 2-11, following):

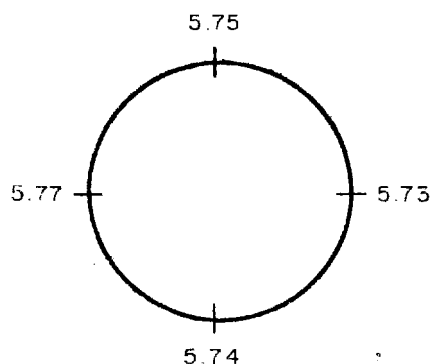


Figure 2-11. Check Points for Static Pressure
(Inches Mercury)

The variation noted was considered insignificant in the context of this phase of the test program.

The blower and capstan were then removed from the test setup and a special adaptive flange built and attached to the inlet of the blower housing so that it could be used as a vacuum pump. In this mode, it was attached to the outlet of the flowmeter and its output measured (Table 2-4, Run 6). This figure was 104.71 cfm, 10.5 percent higher than when the unit was used as a blower. When an attempt was made to duplicate Runs 4 and 5, various problems with the equipment were encountered (Runs 7, 8, 9 and 11 were eliminated by mechanical

TABLE 2-4. Blower Output and Capstan Efficiency (Vacuum Mode of Operation)

Run	Room Temp. T ₁ °F	Plenum Temp. T ₂ °F	Inches Hg P ₁	Inches Hg P ₂	Flowmeter Reading	Time	Corrected Flow CFM
6	78.36				221	0	
	78.96				223	2 min	
	79.25				225	4	
	79.58				227	6	
	79.83				229	8	
	80.03				231	9 min, 39.2 sec.	104.71
7	(Eliminated when Capstan was drawn into Plenum by Vacuum)						
8	(Eliminated when bottom of Barrel started caving in. Bottom re-inforced with stanchions).						
9	(Eliminated because of leaks in Barrel. These were filled).						
10	77.09		5.82		242	0	
	77.32		5.77		243	3 min	
	77.42		5.77		244	6	
	77.52		5.78		245	9 min, 6.7 sec.	33.14
11	(When all leaks repaired and Vacuum applied with all Orifi closed, Barrel started to collapse. Run discontinued and Apparatus disassembled).						
12	73.37		3.85		(P ₁ @ Orifice No. 10, all others open)		
13	73.40		6.22		(P ₁ @ Orifice No. 10, all others closed)		
14	73.37			7.53	(All Orifi closed)		

failure). Run 10 shows a total flow, all orifi and the venturi plenum open, of 33,14 cfm, 8.4 percent more than when the unit was connected as a blower. Runs 12, 13 and 14 were measurements of static pressure made with the fan connected directly to the capstan in a bench setup. The total area of all the orifi was 0.178 square inches and that of the venturi plenum 0.131 square inches (with a 7-mil gap adjustment), giving a total of 0.309. These data are presented graphically together with manufacturer's characteristic curves (Figures 2-12 and 2-13). In both cases, blower and vacuum setups (Figure 2-13), the fan efficiency and the cfm output were higher than would be expected from the manufacturer's data.

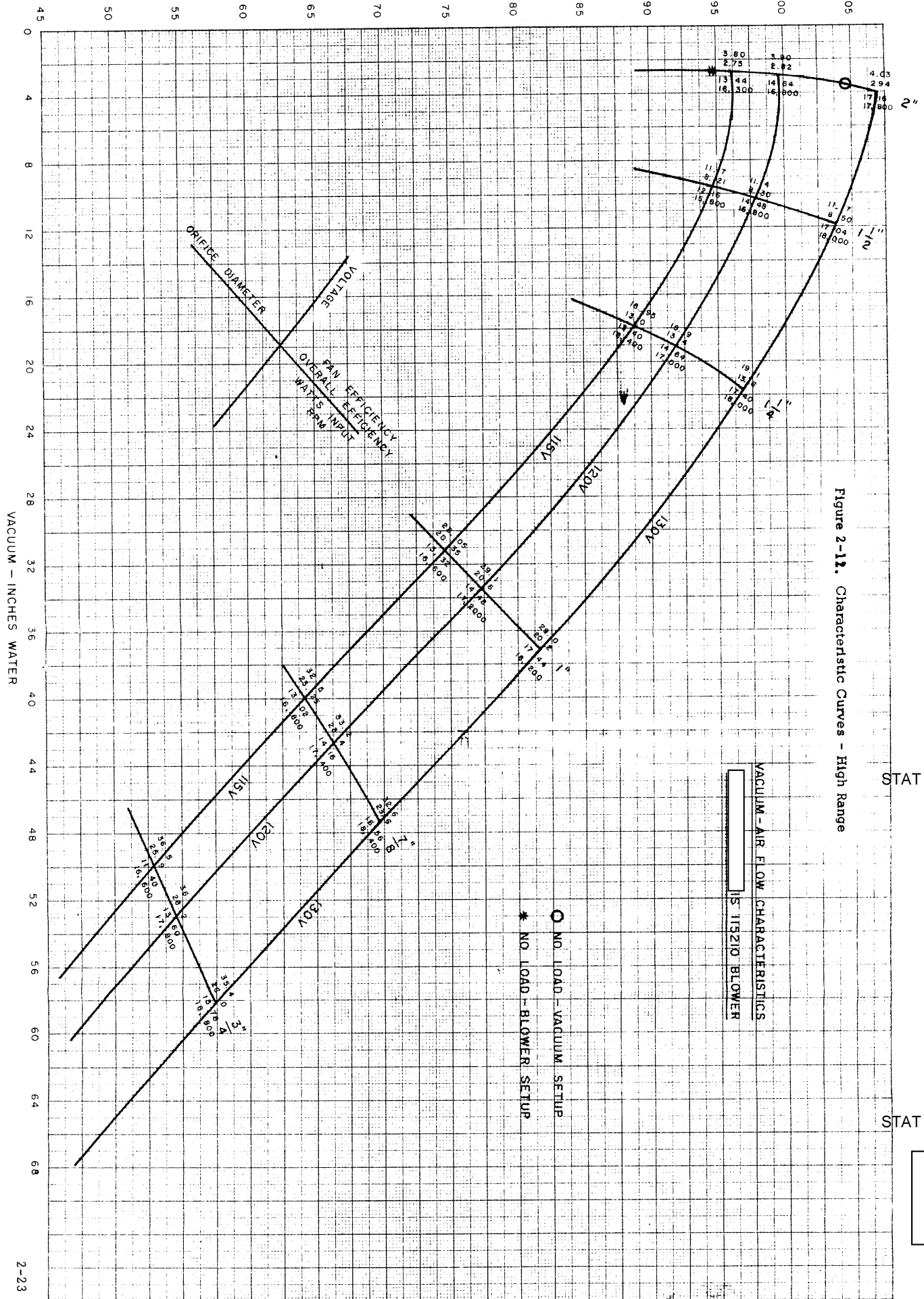
2.4 FILM TORQUE MEASUREMENTS

The final phase of the evaluation program was to measure maximum torque obtainable with different widths of film under varying operational conditions. Four widths of film were used, 70mm, 5-inch, 6.6-inch and 9-1/2-inch. The types and physical specifications are listed (Table 2-5). The capstan was remounted on a 5-foot high test stand and the blower adjusted for its pressure mode of operation. Capstan speed was constant throughout all tests at 17 rpm. The test setup is illustrated (Figure 2-14, following):

(Continued on Page 2-26)

K&E 10 X 10 TO THE CENTIMETER 47 1516
25 X 31 CM • ALBANY, N.Y. MADE IN U.S.A.
KUFFEL & ESSER CO.

AIR FLOW - CFM



10 X 10 TO THE CENTIMETER 47 1516
 K. E. FEUFTEL & ESSER CO. ALBANY, N. Y.

AIR FLOW - CFM

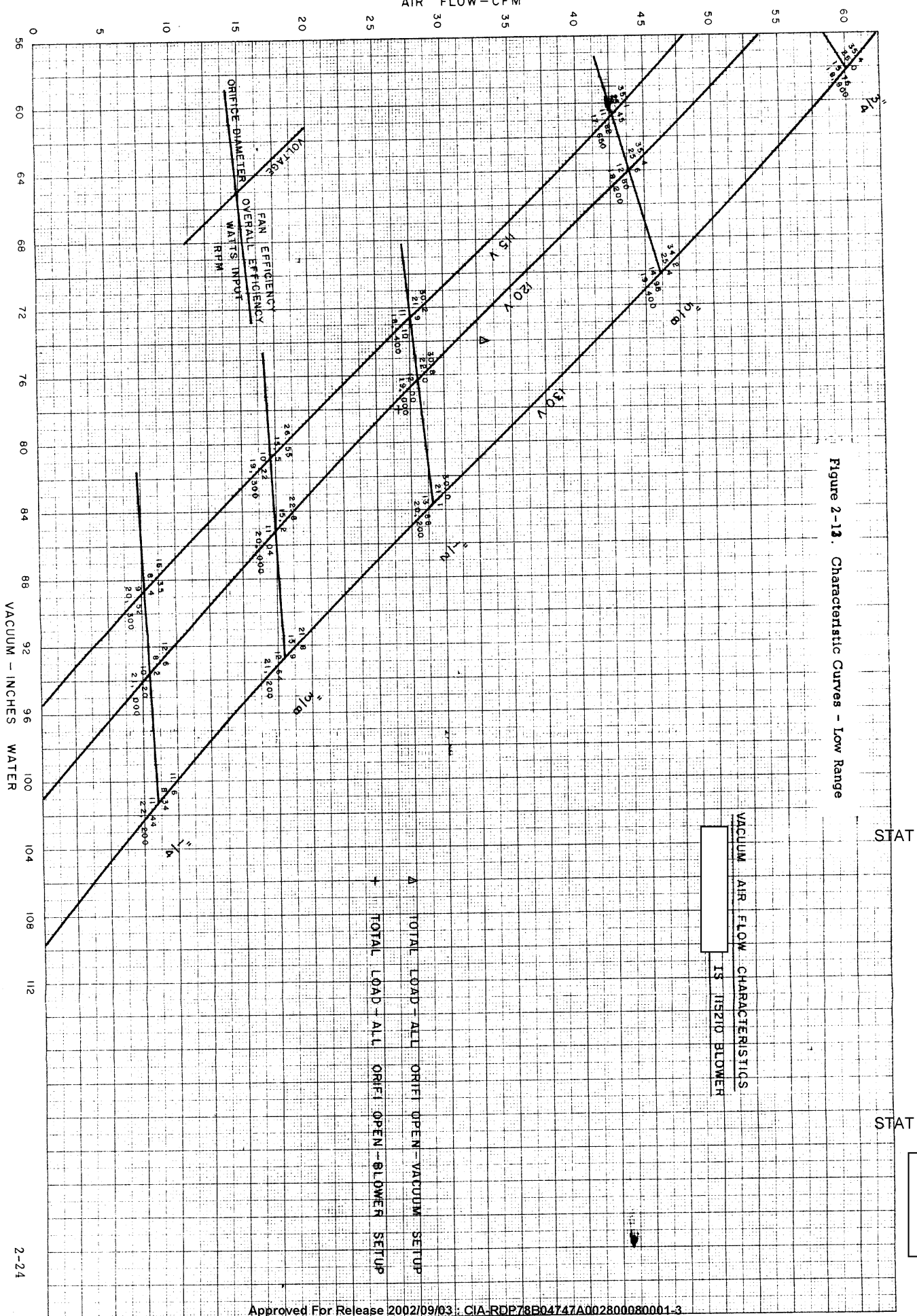


TABLE 2-5. Film Types Used in Vacuum Capstan Test

Size	Film Type	Base Thickness Mils	Emulsion Thickness Mils	Gel Backing Mils	Type of Base
70mm	228R	4.0	-	-	Polyester
5-inch	4404	2.5	0.24	0.26	Polyester
6.6-inch	8430	5.6	0.16	-	Triacetate
9-1/2-inch	4404	2.5	0.24	0.26	Polyester

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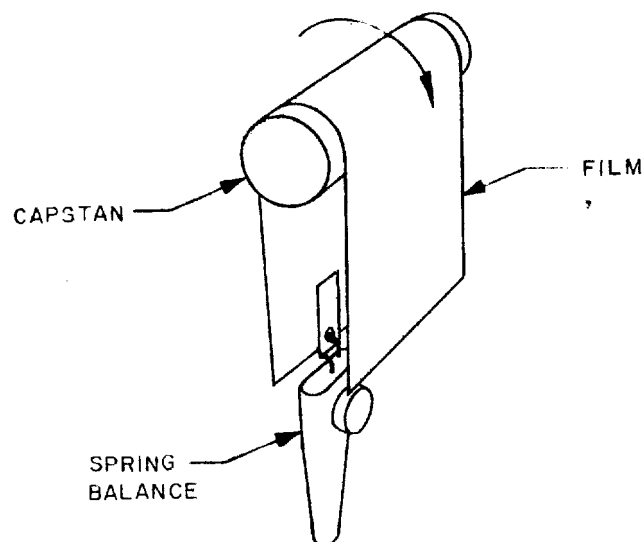


Figure 2-14. Film Torque Test Setup

The film was given a 180-degree wrap on the capstan and a spring balance, or dynamometer, mounted vertically on a rigid support. Two different instruments were used for the measurements, a [redacted] Model DPP-5, Serial No. 2740, with a maximum scale reading of 5 lbs. in increments of 0.05 lbs. and a [redacted] Model L-20, Serial No. 1170, with a maximum scale of 20 lbs. in increments of 0.2 lbs. Before each test, the capstan cylinder was wiped clean with isopropyl alcohol and dried. Maximum torque was recorded at the point that the film slipped on the capstan. The results of the test runs are recorded (Tables 2-6A, 2-6B, 2-7A, and 2-7B). Because of the natural coherence of the film to the capstan when wet, torque readings of the same magnitude (over 14-inch-pounds) were obtained with wet film and no vacuum as were with dry film and the vacuum, compare Run 8 with Runs 2 and 3 Table 2-6A. As would be expected, dry film with no vacuum showed a

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(Continued on Page 2-31)

TABLE 2-6A. Torque Tests on Vacuum Capstan (Pressure Mode)

Run	Film	Procedure	Width	Slot	Reading Lbs.	Room Temp. °F	Torque In.-Lbs.
1	(a) Dry	Vacuum	9-1/2-Inches	7 mils	3.13	74.46	9.39
2		"	"	"	4.82	74.51	14.46
3		"	"	"	4.76	74.55	14.28
4		"	"	"	4.22	74.62	12.66
(a) Film unsteady. As vacuum took hold, wrap increased more than 180° and reading increased in jerks.							
5		Vacuum	9-1/2-Inches	7 mils	5.32	74.72	15.96
6		"	"	"	6.21	74.77	18.63
7		"	"	"	6.24	74.78	18.72
8		No vacuum	"	"	4.76	74.80	14.28
9		"	"	"	3.34	74.80	10.02
10		"	"	"	4.32	74.80	12.96
11		"	"	"	0.25	74.80	0.75
12		"	"	"	0.31	74.80	0.93
13		"	"	"	0.35	74.80	1.05

TABLE 2-6B. Torque Tests on Vacuum Capstan (continued)

Run	Film Dry	Film Wet	Procedure	Width	Slot	Reading Lbs.	Room Temp. OF	Torque In.-Lbs.
14	x		No Vacuum	70mm	7 mils	0.03	73.80	0.09
15	x		"	"	"	0.03	74.16	0.09
16	x		Vacuum	"	"	4.91	74.20	14.73
17	x		"	"	"	6.01(a)	74.17	18.03
18	x		"	"	"	4.97	74.17	14.91
(a) Variation in pull on spring balance noted.								
19		x	No Vacuum	70mm	7 mils	6.41	74.16	19.23
20		x	"	"	"	1.2(b)	74.20	3.6
(b) With film thoroughly wet down, a coherent film of water next to capstan prevented drag friction.								
21		x	Vacuum	70mm	7 mils	18.2 ^{+(c)}	74.33	54.6
(c) As soon as water film was removed, film stuck to capstan and film loop support broke at 18.2 pounds.								
22		x	Vacuum	70mm	7 mils	24 ^{+(d)}	74.42	72+
(d) Run was discontinued. Balance has stop at 25.6 lbs., 5.6 lbs. over scale.								

TABLE 2-7A. Torque Tests on Vacuum Capstan (Vacuum Mode)

Run	Film Dry	Film Wet	Procedure	Width	Reading Lbs.	Room Temp. OF	Torque In.-Lbs.
1	x		Vacuum	9-1/2-Inch	15.5(a)	78.5	46.5
(a) Pressure fairly steady. Supporting tape broke at 15.5							
2	x		Vacuum	9-1/2-Inch	15.8	79.27	47.4
3	x		No Vacuum	"	0.5	79.32	1.5
4	x		Vac. + Release	"	15.5-0.6	79.35	46.5 - 1.8
5		x	Vacuum	"	16.6-22(b)	79.47	49.8 - 66
(b) Action jerky. When water cushion removed, film adhered to capstan							
6		x	Vac. + Release	9-1/2-Inch	25.3(c)	79.66	75.9
(c) Small capstan drive screw loosened and jammed rotary motion							
7		x	Vac. + Release	9-1/2-Inch	24.9(d)	79.57	74.7
(d) Capstan maintained 24.9 lbs. (film under tension and papping with each slippage), however, releasing vacuum did not change reading.							
8	x		Vacuum	6.6-Inch	18.5	79.47	55.5
9	x		"	"	16.6	79.47	49.8
10	x		No Vacuum	"	0.4	79.48	1.2
11	x		Vac. + Release	"	16.3-0.7	79.56	48.9-2.1
12		x	Vacuum	"	25.0	79.57	75
13		x	Vac. + Release	"	25.1	79.61	75.3

TABLE 2-7B. Torque Tests on Vacuum Capstan (Continued)

Run	Film Dry	Wet	Procedure	Width	Reading Lbs.	Room Temp. °F	Torque In. - Lbs.
14	x		Vacuum	5"	21.5 (a)	79.72	64.5
(a) Apparently frictional forces in thin dry film develop considerable static electricity which tends to make film adhere to capstan tenaciously.							
15	x		Vacuum	5"	22.4	79.71	67.2
16	x		Vac. & Release	"	22 ⁺ - 0.6	79.70	66 ⁺ - 1.8
17		x	Vacuum	"	20.2	79.69	60.6
18		x	Vac. & Release	"	12.3-2.1	79.69	36.9-6.3
19		x	Vacuum	"	13.9 (b)	79.70	41.7
(b) With new film strip.							
20	x		Vacuum	70mm	8.1	79.62	24.3
21	x		Vac. & Release	"	7.8-0.3	79.56	23.4-0.9
22		x	"	"	25.0-21.9	79.52	75.0-65.7
23		x	Vacuum	"	25.0	79.54	75.0

torque in the range of only one pound. An unexpected result, however, was the high torque readings (as high as 72-inch-pounds versus 18.72) obtained with the 70mm film compared to the 9-1/2-inch film. Since the force acting on the film is atmospheric pressure, it should vary proportionately to the exposed surface, being higher for wider films. The difference must lie in the characteristics of the film itself, one type presenting a much higher frictional surface than the other. Time did not permit examining this anomaly.

The apparatus was disassembled and rebuilt with the blower connected in its vacuum mode. The results are tabulated (Tables 2-7A and 2-7B). For this series, the venturi slot was opened up to 27 mils to obviate the constrictive effect of reversing the flow pattern and then sealed with a strip of mylar splicing tape. The torque for dry 9-1/2-inch film was increased about three fold, 47.4-inch-pounds versus 14.5, and about four times for wet film, 75.9-inch-pounds versus 18.7. The results for the other widths and conditions are tabulated and annotated.

A new technique was employed in this series wherein the vacuum was applied to a maximum torque reading and then released. This procedure would not occur in practice (unless the vacuum system failed), but was employed to determine how much frictioned force was generated between the film and the capstan surface irrespective of the vacuum. In the case of the thin-base 5-inch polyester, exceptionally high readings, 64.5 to 67.2-inch-pounds, were obtained probably due to

static charges developed in the dry film. This was attested by the wrap exceeding 180 degrees during test. In all other cases, the wet torque measurements exceeded those made with the film dry.

SECTION 3

CONCLUSIONS

3.1 TYPES OF TRANSPORT CAPSTAN

There is no question of the superiority of a capstan operated so that a vacuum fan withdraws air from a plenum connected to its surface by orifi, over one in which the vacuum is generated by a blower and venturi principle - all other factors remaining constant. The capacity of the fan itself was increased 10.5 percent when connected in the vacuum mode.

Since all of the tests embodied in this report were made on a single capstan design, it should not be erroneously concluded that this is an optimum configuration. A lower vacuum spread over a larger area would theoretically give increased torque readings, but might require format changes. No intensive investigation of porous membranes, particularly ones which were inexpensive enough to be discarded periodically, has been made. Such an extension of this project should prove valuable.

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